November 21, 2014

PACMAN on Mars: Multi-Functional Orbiting NanoSatellite Platform

Power And Communications with a Modular Array of Nanosatellites

Author

Jeff Harvey, Structures and Mechanisms

MMA Design tjharvey@mmadesignllc.com

Concept Collaborators

Don Brown, Avionics and Software

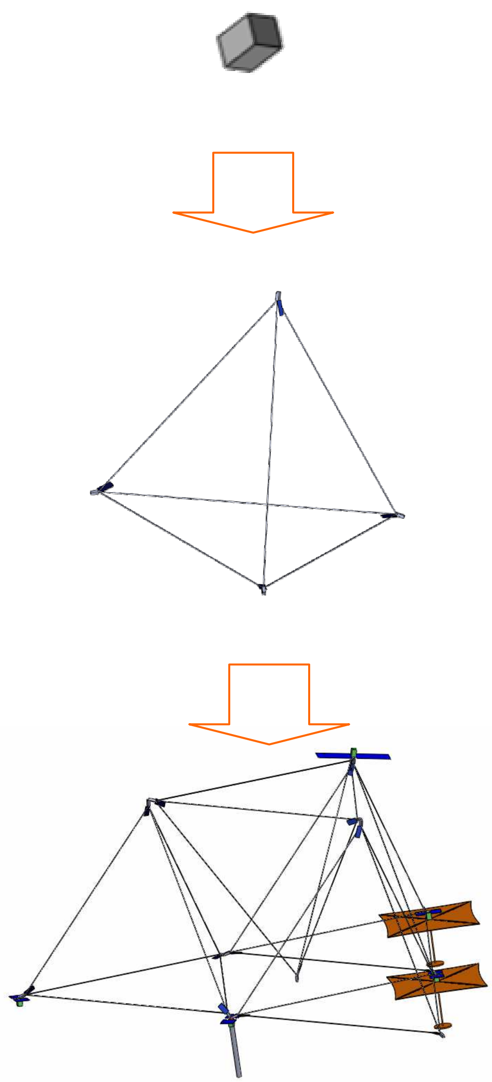
Tiger Innovations

Pamela Clark, Science Mission Concepts

NASA GSFC/Catholic University

PACMAN Platform Concept

- PACMAN is an array of deployable NanoSatellites
- Provides an infrastructure interface system that allows pooling of instrument platform resources
  - Adds a vehicle's capabilities to the collective
  - Dormant or retired systems continue to add to the net capability
  - Instruments can function collaboratively to produce data neither could do independently
  - Can save a malfunctioning instrument system
- Enables flexible and cost effective fielding of a variety of scientific instruments

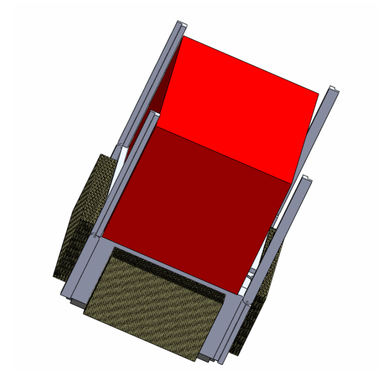


PACMAN Enables Infrastructure Sharing

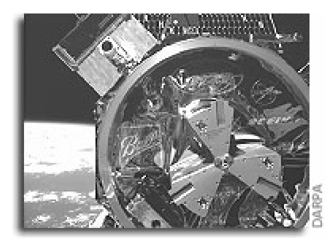
- Small form factor spacecraft (CubeSats, NanoSat, etc.,) have limited capability due to size constraints
  - Power
  - Communications
  - Attitude control (ACS)
  - Command and Data Handling (CDH)
- Infrastructure hardware often consumes about half of a NanoSat's volume
  - Limits instrument volume
  - Volume is at a premium in a CubeSat
- Access to Mars is extremely difficult to achieve
- Through resource pooling PACMAN provides or improves
  - Electric Power System
  - Command and Data Handling
  - Attitude Control System
  - Propulsion
  - High speed communication links
  - Various other bus infrastructure (low-drift clock, etc.)
- Can lower total mission cost
- The large deployed structure of PACMAN meets the positional knowledge requirements for some instruments requiring disaggregated sensors
  - Sparse apertures
  - Interferometers
- Physical connectivity
  - Increases reliability
  - Requires minimal fuel for transit and space docking
  - Can have fuel/ACS payloads added over time as needed

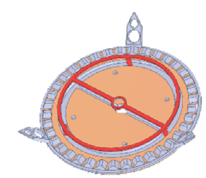
Changes the Way Instruments are Fielded and Resources are Used

- Creates a service providing infrastructure on an as needed basis
  - Allows *sensor* to be bulk of payload
  - Primary Power comes from the platform
  - Primary attitude control from the platform
  - Interplanetary Communication resources are provided and used communally
  - Increase payload to housekeeping volume percentages
- Docking to a PACMAN
  - Standardized docking ports for any mass compliant vehicle
  - Standardized Payload Transport Vehicle
    - To get an instrument to the PACMAN
    - Standardized volumes, electrical, mechanical and software interfaces
  - Simple, reliable, cost effective infrastructure for sensor systems



Payload Transport Vehicle Concept

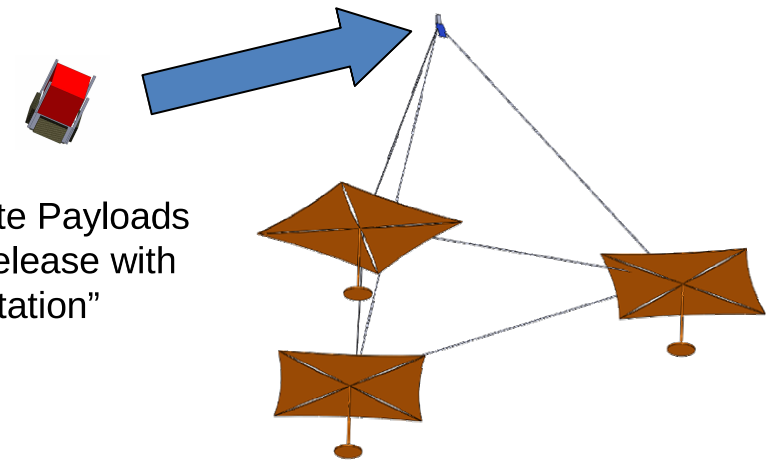




Standardized Docking Port

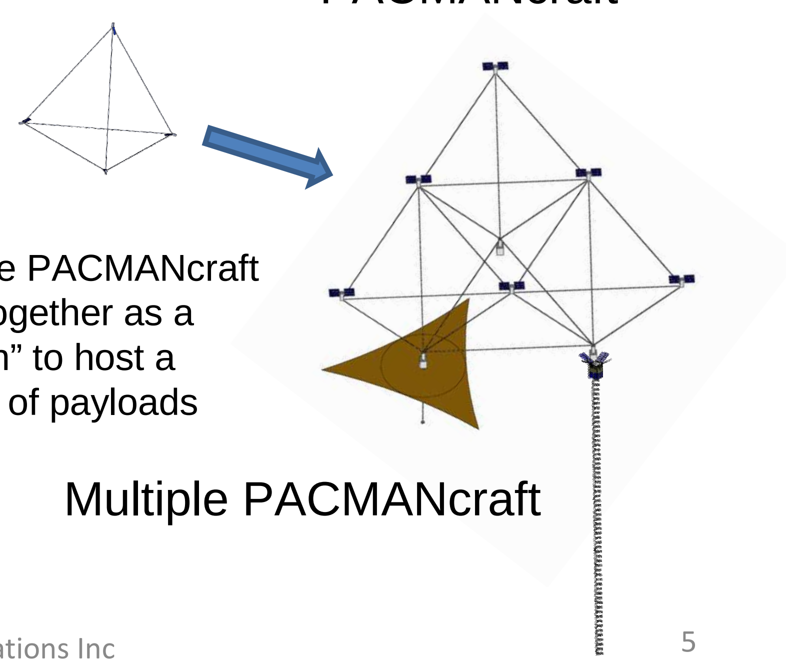
Base Infrastructure

- Docking
  - Semi-autonomous or man in loop docking
  - Use technology developed by DARPA
    - Orbital Express
    - F6
- Each PACMANcraft is stand alone
  - Can dock 4 or more science mission craft
  - Each PACMANcraft has excess capabilities to augment payloads
- Multiple PACMANcraft can be docked to form a large system
  - Each hosted mission craft requires limited propulsion
  - Expandability allows very large structures
- Assembled in space
- Special modules can be added to augment
  - Maneuverability (Propulsion)
  - Up front processing
  - Special power needs
  - Large antennas/Communications



Separate Payloads dock/release with “station”

PACMANcraft



Multiple PACMANcraft dock together as a “station” to host a variety of payloads

Multiple PACMANcraft

Potential Mars Science Payloads for PACMAN

Some Potential Mars Science Orbital Payloads and Applications			
Description	**Compact Payload**	**Example**	**MEPAG Goals**
Characterize seasonal/event variations in Water and other Volatile Distribution on Mars Surface	broadband IR Spectrometers	BIRCHES	II.A.1, 3: water, volatile exchange, and dust on all scales, III: evolution of surface and interior of Mars
Characterize Mars seasonal and global event variations in temperature, emissivity, soil distribution	Thermal emission spectrometers	TIS	II.A.1, 3: water and dust on all scales
Characterize Mars solar events and Seasonal Changes on atmosphere, ionosphere, magnetic anomalies at various altitudes	Ion Spectrometers, Magnetometers, Plasma Analyzers	QB50 INMS	II.A present atmosphere variations, composition; III: magnetic field, interior and thermal evolution
Characterize Mars Neutral Atmosphere, including trace gases, variations and loss at various altitudes	Mass Spectrometer, specialized sensitive gas sensors (e.g., atmospheric solar occultation using echelle spectrometer with acousto-optical tunable), lyman alpha H/D photometer	SOIR (Solar Occultation InfraRed Venus Express Orbiter), LAP (Lyman Alpha Photometer Indian Mars Orbiter)	II.A volatile exchange, constituents, clouds
Multi-platform imaging	Compact Visible/IR Camera	JPL CubeSat Science Camera RFI	II.A: lightning detection, dust on all scales, III: evolution of surface and interior
Characterize atmosphere dynamics as function of altitude, latitude, terrain, global events and seasons	Drop Probes with Temperature, pressure, neutral and charged atmosphere components, dust detectors, cubesat aerobraking deployable shields	ARMADILLO PDD (Piezo dust detector)	II.A: present atmosphere, winds, clouds

Potential Science Objectives

Possible mission configurations
Orbiters – Orbiter Networks – Phobos Lander CubeSats – Mars Rover Piggyback

Science Theme	Relevant MEPAG/HEO Goal	Measurement	Instrument
Weather monitoring	MEPAG Goal II: Understand processes of climate on Mars, characterize Mars' present climate/atmosphere II.A.1,3: Water & dust on all scales, volatile exchange HEO: Effects of dust	Presence of dust clouds and water clouds	Camera
Atmospheric profiling (T,P, etc.)	MEPAG Goal II.A: Characterize Mars' present atmosphere. HEO: Improved atmospheric modeling	Temperature, pressure , dust concentration, etc. profile vs. altitude	Atmospheric Radio Occultation
			Atmospheric Light Science
Atmospheric composition	MEPAG Goal II.A.1,3: Water, CO_2 on all scales, volatile exchange HEO: Atmospheric constituents	Atmospheric chemical composition	Mass Spectrometer
			Sub-mm wave spectrometer
		Atmospheric water vapor concentration	Microwave Radiometer
		Atmospheric dust/micro-meteorite concentration	Dust Detector
Atmospheric winds	MEPAG Goal II.A: Characterize Mars' present atmosphere	Atmospheric wind speed & direction vs. altitude	Lidar
			Sub-mm wave spectrometer
Cloud properties	MEPAG Goal II.A.1,3: Water on all scales, volatile exchange	Cloud properties	Polarimeter
Surface mineralogy	MEPAG Goal III: Determine evolution of surface of Mars. HEO: Geology/composition of Phobos and Deimos	Mineralogy	Imaging Spectrometer
Gravity field	MEPAG Goal III.B.1: Understand evolution of Mars' interior	Measure gravity field (high order J-terms)	Gravity Light Science Investigation
			Gravity Field Formation Flight
Lightning detection	MEPAG Goal II.A: Characterize Mars' present atmosphere. HEO: Atmospheric electricity	Radio signals from lightning	Radio detector
		Light flash from lightning	Photodiode
Magnetometry	MEPAG Goal III.B.2,3: Understand evolution of Mars' interior magnetic field, thermal evolution of planet	Magnetic field	Magnetometer
Radiation	HEO: Radiation	Radiation environment	Radiation Detector
		Total radiated dose	Dosimeter
		Solar wind	Plasma Instrument
		Neutron detection	Neutron Spectrometer

CubeSats are well suited to address narrowly focused MEPAG & Decadal Survey goals & investigations, rather than complex multifaceted questions

